DEFENSE WASTE PROCESSING FACILITY INTEGRATED COLD RUNS

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ABSTRACT

The Defense Waste Processing Facility (DWPF) is being constructed at the Department of Energy's Savannah River Plant (SRP) which is operated under contract by E. I. du Pont de Nemours and Company. The primary mission of the DWPF is to convert the radioactive waste, presently stored in underground tanks, to a more stable form, borosilicate glass, for eventual storage in a federal repository.

The Office of Civilian Radioactive Waste Management is responsible for determining the criteria for waste acceptance at a federal repository. These requirements are contained in the Waste Acceptance Preliminary Specification (WAPS). Each waste producer is responsible for developing a Wasteform Compliance Plan (WCP) designed to meet these specifications. Data from tests described in the WCP will be reported in the Wasteform Qualification Report (WQR). Six of these: control of radionuclide release, verification of radionuclide release control, chemical and physical stability, free volume, free liquid, and fabrication and closure require demonstration of full-scale operation of the production facility to satisfy the WAPS documentation requirements.

As the facilities are completed by Construction, they are turned over to Production to perform checkout and run-in testing using water. The support facilities such as the power and water systems are then placed online to permit testing of process facilities. Operation of the primary radioactive processing facilities using nonradioactive simulated feeds, the Integrated Cold Run Plan, will be implemented just before radioactive operation of the facility. The plan integrates the operation of the process facilities, using simulated feeds, to provide the documentation needed for the WQR while demonstrating the overall process functionality to confirm operating conditions and procedural requirements.

DISCUSSION

In the manufacture of fissile materials for the Defense Department, high level radioactive wastes are produced. At the Department of Energy's Savannah River Plant (SRP), operated under contract by E. I. du Pont de Nemours and Company, these wastes are currently stored in underground tanks which are monitored and controlled to prevent release to the biosphere. In conjunction with national policy, the Department of Energy has obtained funding to construct the Defense Waste Processing Facility (DWPF) at the Savannah River Plant. The primary mission for this facility is to convert the radioactive waste into a more stable form, borosilicate glass, for eventual storage in a federal repository. The design basis for the DWPF exceeds the annual waste production forecast so that the inventory of waste in tanks can be reduced and future use of waste tanks minimized.

The DWPF involves six major activities in producing the desired product, i.e., the wasteform package. Basically these activities are: hydrolysis of a precipitate used to remove cesium from the aqueous waste salt stream, chemical reduction of the solid sludge to remove mercury which is incompatible with the glass, formulation of the borosilicate glass composition by addition of a special glass frit, dehydration and calcination in a joule-heated, liquid-fed ceramic melter, treatment of the melter offgas to permit atmospheric discharge, and pouring of the borosilicate glass into a canister which is decontaminated and sealed prior to onsite storage.

Considerable work has been done in development of these processes by Savannah River Laboratory (SRL) personnel. Operation of semiworks facilities by the laboratory has also been performed with scale up of the liquid-fed ceramic melter to about 45% of full capacity and operation of a prototypical vessel for chemical reduction, without mercury, to demonstrate solids handling and heat transfer characteristics. Mercury was not used full-scale because of the high cost of constructing a tight system to control environmental mercury hazards. During design and purchasing activities, demonstration performance tests were run on key equipment pieces to ensure their operability. Demonstration of a full-scale melter was not warranted since design scale-up factors are well known and costs would have been excessive.

DWPF is currently under construction. As the individual facilities or systems are completed, they are turned over to Production to perform checkout and run-in testing using water. When support facilities such as the power, steam and water systems have been tested, they are placed online to permit testing of process facilities which require these services.

The Office of Civilian Radioactive Waste Management is responsible for determining the federal repository waste acceptance criteria. These criteria have been formulated into the Waste Acceptance Preliminary Specification (WAPS). Each waste producer is responsible for meeting the WAPS and is required to develop a Wasteform Compliance Plan (WCP) to show how each of the individual specification requirements will be met. Data from tests described in the WCP will be documented in the Wasteform Qualification Report (WQR).

Operation of the primary radioactive processing facility using nonradioactive simulated feeds, the Integrated Cold Run Plan, will be implemented just before radioactive operation of the facility. The plan has two major objectives:

to demonstrate the overall functionality of the process and auxiliaries so operating conditions and procedural requirements can be confirmed and to provide the technical data for the WQR.

DEMONSTRATION OF OVERALL FUNCTIONALITY

Before radioactive operation of the DWPF, overall functionality of the process must be demonstrated. This involves characterization of the melter, demonstration of sampling accuracy, mercury recover, corrosion/erosion evaluations, and demonstration of offgas decontamination.

Although the design scale-up factors for a ceramic melter are well known, the operational control and performance data must be developed for each individual melter design. Melter characterization will be the initial objective of the Integrated Cold Runs since it provides the baseline data for all other evaluations. Based on SRL scale-melter work, a program for gradual heatup of the melter, using the dome heaters, will be employed to minimize thermal differentials within the ceramic bricks. After the melter reaches about 650°C, joule heating will be initiated through the glass frit which has been previously charged to the melter. Once the melter has reached the operating temperature, about 1100°C, liquid feed will be started at low rates and the melter gradually increased to the normal operating level. Melter operating conditions, using a standard feed, will be confirmed and characterization of response to dome temperature control, electrode power distribution, melt resistivity, feed distribution, and melter temperature profile will be evaluated. Operation of the melter drain valve and tuning of the offgas system will also be performed at this time. Characterization of temperature profile, resistivity, electrode power distribution, and drain valve operation as a function of feed composition will be integrated with tests required to satisfy the WAPS.

Remote sampling facilities have been incorporated into the DWPF design. A prototypical system has been evaluated at the SRL. A series of sampling demonstrations will be performed in the plant facilities to confirm sampling accuracy for vapor, liquid, and slurry streams. These demonstrations will be integrated with determination of the analytical accuracy for the DWPF laboratory since melter feed analysis is a primary determinant for melter operation and glass quality.

Mercury oxides are essentially incompatible with borosilicate glass. Therefore removal is essential to prevent the buildup of a large mercury recycle stream. Because of the environmental hazards associated with mercury handling and the high cost of constructing full-scale enclosed facilities to handle mercury, experimental tests have been limited to those on a laboratory scale. A special test designed to use mercury in the production facility will be made to demonstrate mercury removal before radioactive operation. Although laboratory corrosion evaluations have been performed using mercury, chlorides, and fluorides in simulated feeds to specify materials of construction, no tests have been performed under actual operating conditions. This mercury test will permit initial corrosion evaluations to ensure that the DWPF has no catastrophic material incompatibility problems.

In addition to corrosion, erosion because of the solids handling performed in the processing vessels and the effect of the melt on the melter ceramic brick are a concern. Plans to evaluate the solids handling erosion and for remote inspection of the melter brick have been incorporated into the overall Integrated Cold Run Program. Comparison of this information with SRL data will be made to confirm expected wear rates. Remote examination of the melter will provide invaluable data for comparison with results of examinations to be performed after radioactive operations have commenced.

The melter offgas contains both semivolatile and particulate radionuclides which cannot be discharged to the atmosphere. Decontamination of the melter offgas by a factor of 10^8 is required to permit discharge. Analytical measurements of nonradioactive ingredients in the offgas are too inaccurate to measure decontamination factors of this magnitude. Therefore, a radioactive spike test is planned to evaluate the offgas decontamination capability without committing the full range of activity associated with the high level waste to the facility.

COMPLIANCE WITH WASTEFORM REQUIREMENTS

The WAPS contains twenty major criteria. Of these, six require full-scale operation of the production facility to satisfy the WAPS as proposed in the WCP. Documentation of this information will be in the WQR. The following plans have been developed as part of the Integrated Cold Run Plans to satisfy this requirement.

One of the six required demonstrations is for Control of Radionuclide Release. Radionuclide release is the rate at which the wasteform will leach its radioactive contents to the biosphere, i.e., the leach rate. SRL has performed extensive studies on leach rates for various glasses. These data show that the leach rate is primarily a function of glass composition and temperature history. If the glass has a standard temperature history, i.e., passes through the transition (devitrification) temperature range in a reasonable time frame, then the leach rate is basically dependent only on composition. Since the chemistry associated with dehydration and calcination in the melter is well known, the glass composition is directly related to the liquid feed composition. Since the WAPS sets a limit on radionuclide release rate (leach rate) for the canistered waste form, it is then possible to define an envelope of feed compositions which will produce glass with release rates which are within the specifications. The WAPS requires that the glass composition be reported for the canisters; this will be accomplished by using the melter feed analysis and converting it to the glass product by using a melter algorithm. The melter algorithm must define the glass product over the anticipated range of feed compositions. Current

SRL data indicate that the melter acts like a continuously fed, constant-level well-mixed tank and that the composition change can be defined by the equation

$C = C_0(1 - e^{-Ft/V})$ where C is the current composition, C_0 is the composition at time zero, F is the feed rate, t is the duration since feed of the new composition was initiated, and V is the constant volume in the tank. When the range of compositions that are anticipated for DWPF is evaluated, it is expected that the viscosity of the melt will vary between 20 and 100 poise with a norm of about 60 poise. Demonstrating that the production melter operates according to the well-mixed-tank formulae is essential to defining the melter algorithm. Four tests will be conducted to confirm this relationship: operation at the nominal viscosity using a chemical tracer, conversion to a low viscosity glass feed composition, conversion to a high viscosity glass feed composition, and finally conversion back to the nominal viscosity glass. The initial test will define the mixing characteristics of the melter under nominal viscosity conditions while the other tests will confirm the mixing characteristics of transitional and extreme viscosity conditions. This series will also provide data for characterizing melter operating conditions versus composition. Analysis of the equation for composition change shows that when the tank contents have been displaced once, i.e., one turnover volume when the exponent Ft/V equals one, 63.2% of the incremental composition change has occurred. Table I shows the relationship between turnover volumes and percent change in incremental composition.

TABLE I
Relationship Between Turnover Volumes and Percent Change

Turnover Volume	% Composition Change
1	63.2
2	86.5
3	95.0
4	98.2
5	99.3
6	99.8

Since it is desirable to characterize the melter at the limiting conditions and to provide the optimum analysis of the mixing characteristics for melter algorithm confirmation, six turnover volumes have been selected as the quantity of material to be produced for each of the test conditions. For the DWPF melter design, this relates to 90,000 pounds of glass per test.

Verification of radionuclide release control specifications in the WAPS requires sampling of the product after radioactive operation has begun. Since the glass is highly radioactive, only small quantities can be safely handled in the laboratory. A sampler has been developed which takes a grab sample of approximately 35 grams while a canister is being poured. This sample must be removed from the melt cell using the main process cell crane, packaged in a cask and transported to the SRL for analysis. A correlation between the glass sample and the glass in the canister is required to show that the sample is representative of the canister contents. Samples will be taken of the glass produced during tests for the control of radionuclide release. The chemical analyses of these glass samples will be compared to analyses made on glass samples obtained by sectioning the companion canister. Reliance is placed on the chemical analysis since the sample and canister will have different thermal histories which might influence other types of analysis such as leach rate. Sufficient data are available from SRL tests to correlate leach rate versus composition for full-scale canisters.

Another requirement of the WAPS is to demonstrate chemical and physical stability. These properties are both composition and temperature dependent. SRL data confirm that chemical composition remains stable over the range of compositions anticipated. Phase stability is dependent primarily on the thermal history of the glass. Laboratory data show that for normal canister thermal history, i.e., normal transition through the devitrification temperature range, the leach rate is not significantly affected by the phase changes that occur. Glass with the normal thermal history meets the radioactive release control criteria. Some of the canisters used for the Integrated Cold Runs will be equipped with thermocouples to confirm the cooldown profiles measured in the semiworks. Measurements will also be made with canisters placed in the DWPF insulated storage racks to determine their influence on the cooldown profile.

The WAPS states that the repository package shall have no more than 20% free volume. The DWPF has three methods of determining the free volume: weight, neutron adsorption, and gamma radiation. Since the Integrated Cold Runs will be performed with nonradioactive simulated feeds, only the weight and neutron adsorption methods will be operational. The weigh cells and neutron sources will be calibrated before the Integrated Cold Runs. During the Integrated Cold Runs, several of the canisters produced will be physically tested for free volume which will be compared to the actual weight and neutron absorption values obtained for these canisters. Gamma radiation from the canister will also be used once radioactive operation begins. Plans are to calibrate the columnated series of detectors using a radioactive source. Once radioactive operation has begun, the gamma detectors will be calibrated against the neutron absorption system.

Because of the potential for leaching radionuclides to the biosphere, the WAPS specifies that the wasteform package have no free liquids. The temperature at which the glass is poured into the canister, >1,000°C, precludes liquids being in the canister once pouring is complete. However, during canister decontamination it is subjected to a water stream which could permit water to enter the canister. To eliminate this potential, a temporary canister closure (inner canister closure) assembly is shrunk fit into the canister opening after the canister is filled but before the canister is decontaminated. This closure will be tested prior to decontamination to ensure that the leak rate is less than 10^{-4}

atms-cc/sec helium which is a watertight seal. During the Integrated Cold Runs, several canisters will be examined for free liquid after decontamination has been completed.

The last criteria in the WAPS that require confirmation in the Integrated Cold Runs are fabrication and closure of the wasteform package. This specification requires that the canister be leaktight to prevent intrusion of gas or liquid before the wasteform is sealed in a repository container. Fabrication of the DWPF canister is done under stringent quality control requirements and records will be incorporated in the WQR. The canister closure is performed by making a resistance weld between the canister and a plug within prescribed force, amperage, and time parameters. A parametric study of these criteria will be made using the production welder to demonstrate the acceptable envelope. During the Integrated Cold Runs, some of the production-line canisters produced will be tested and metallurgical evaluated to confirm weld acceptability.

SUMMARY

The Integrated Cold Run Plan is designed to demonstrate process functionality while proving the information needed to satisfy the WAPS. It is estimated that about 630,000 pounds of glass will be produced over about nineteen months in this effort. The general sequence of this plan is: start up the precipitate and sludge treatment facilities, heat up and build the melter level, characterize the melter operating parameters, perform the tests necessary to satisfy the WAPS requirements, perform erosion evaluations of the solids handling and melter systems, demonstrate mercury recovery, perform corrosion evaluations, and finally demonstrate melter offgas decontamination. Over two hundred activities, from defining simulated feed compositions to documenting the WRQ data, have been defined to carry out this plan. Individual activities have been assigned and the plan has been incorporated into the overall project program.

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